Three Particle Correlation Functions: A Probe for Mach Cones at RHIC

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Abstract: Recent theoretical studies coupled with experimental observations have made away-side jet modification a major theme in the study of medium induced effects at RHIC. Here, we present novel simulation results which point to the use of three-particle azimuthal correlation functions as an important probe for possible "Mach cone" like emissions of away side jet fragments at RHIC.

Keywords: Jets, jet modification, Mach cones,
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INTRODUCTION

The energy density achieved in Au + Au collisions at RHIC, far exceeds the estimate for the QGP phase transition. This energy density gives rise to large pressure gradients which are the driving force for the observed large azimuthal anisotropy (v2) of particle emission from the collision zone. The value of this anisotropy is close to the predictions of the hydrodynamic model which in turn implies the creation of a strongly interacting medium and early equilibration [1]. In addition to the dominant soft processes giving rise to the formation of the medium, there are relatively rare hard parton-parton collisions in which the scattered partons propagate through the medium radiating gluons and interacting with the medium till they finally fragment into jet-like clusters. Thus, jets are a probe of the medium provided one can decompose the jet signal from collective flow effects [2]. Possible medium associated modifications of the jet, as it traverses the medium, are a conical emission due to a “sonic boom” effect [3] and jet-deflection induced via interactions with flowing partons [4]. Three particle azimuthal correlation functions provide a sensitive tool for the study of such jet topologies.

AZIMUTHAL CORRELATION FUNCTIONS

The commonly exploited two-particle azimuthal correlation functions are built by combining a leading hadron in the range $2.5< p_T < 4.0$ with an associated hadron in the range $1.0< p_T <2.5$ [5]. The correlation function $C\left(\Delta\phi\right)$ is given by:

$$C(\Delta\phi) = \frac{N_{\mathrm{Re}al}(\Delta\phi)}{N_{mix}(\Delta\phi)}$$

where $\Delta\phi$ is the difference in azimuthal angle of the pair. The real distribution is built from pair members belonging to the same event and mixed distributions are made of pair members belonging to different events. Thus the correlation function is free of geometric acceptance effects and carries only the physics effects i.e. long range correlations from flow and short range correlations from jets.

Three particle correlations were built in a similar fashion by combining a high p_T particle with two associated low p_T particles. The mixing is was carried out so as to remove all direct three-particle correlations. To facilitate distinction of different jet modification scenarios, correlation functions were obtained in a more natural frame of reference which is the most accessible approximation to the actual jet frame.

Correlation Functions Using the Jet Frame

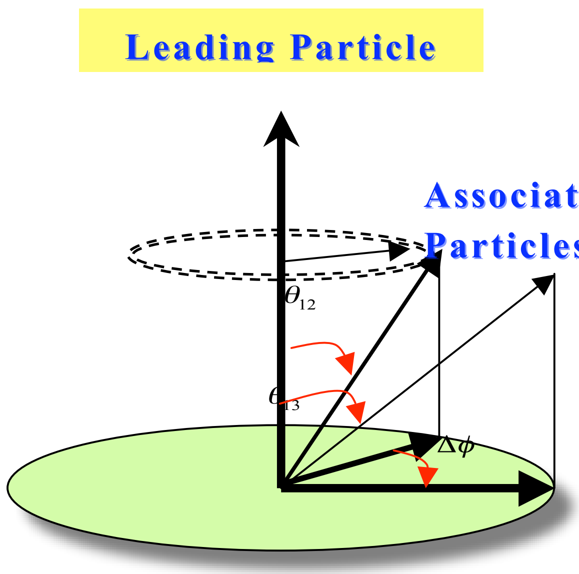

FIGURE 1. Schematic diagram of the coordinate frame used for three-particle correlation functions. The leading (high p_T partcle) is assumed to be the z axis. The polar angles of the associated particles are θ_{12} and θ_{13} respectively. $\Delta\phi$ is the azimuthal angle difference between the two associated particles.

A frame is chosen with the high p_T particle as the z-axis. The polar and azimuthal angles of the associated low p_T particles are then specified in this frame as indicated in Fig. 1. The differences of azimuthal angles $\Delta\phi$, and one of the polar angles θ, are chosen as the correlation variables. A two dimensional distribution $N_{real}(\Delta\phi,\theta)$ is obtained. The corresponding mixed distribution $N_{mix}(\Delta\phi,\theta)$ is obtained via sampling which removes direct three-particle correlations (but not the two-particle correlations).

Results from Simulations

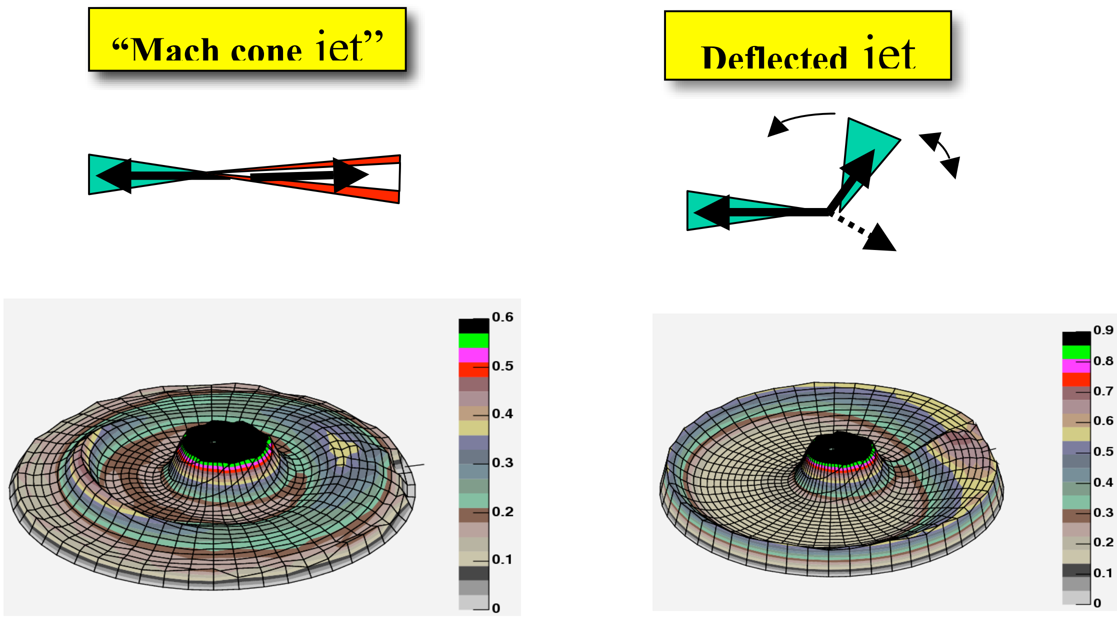

FIGURE 2. Bottom Left panel show the resulting correlation surface for a Mach cone. Bottom Right panel shows the correlation surface for deflected away-side jet (see schematic diagrams in top panels.

Figure 2 shows correlation surfaces obtained for simulations in which Mach cone like emissions and deflected-jet emissions were assumed. The bottom panels of the figure clearly show distinct correlation features characteristic of each assumed model scenario.
Given the distinct nature of these topological features, we conclude the extraction of similar correlation functions from Au+Au data at RHIC, should provide invaluable insights on whether or not “Mach cones” or “deflected jets” are primarily responsible for the large in-medium modification of away-side jets observed via two-particle azimuthal correlation functions [5]. Such correlation measurements of Au+Au data are currently underway.

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